Glass and Ceramics, Vol. 68, Nos. 7 – 8, November, 2011 (Russian Original, Nos. 7 – 8, July – August, 2011)

WASTES USE IN PRODUCTION

UDC 666.762.1-127:621.317.61

PRODUCTION OF POROUS ALUMINOSILICATE CERAMIC USING INDUSTRIAL WASTES

E. V. Bogomazova,[1] B. B. Kalinichenko,[1,2] N. S. Kostyukov,[1] G. B. Shchekina,[1] and T. B. Makeeva[1]

Translated from *Steklo i Keramika*, No. 7, pp. 22 – 24, July, 2011.

The consumable absorber method is use to obtain porous ceramic based on kaolin, talc, and quartz-feldspar raw materials from Amur Oblast. Wastes from rubber mechanicals, crop grains, and woodworking were used as a pore-forming additive. The following were determined for the samples obtained: the open porosity, water absorption, specific surface area, compression strength, and water permeability. The apparent density, total and closed porosity, specific volume of the pores, and the elastic modulus were calculated.

Key words: aluminosilicate porous ceramic, porosity, consumable additives, use of industrial wastes.

In recent years researchers have become increasingly interested in porous materials [1]. The reason is that such materials are widely used in industry as working elements in filters for purification and separation of liquids and gases, carriers for catalysts, membranes with partial permeability, electrodes, fuel and electrolytic elements, and insulation elements. Ceramics occupy a special place in a long list of materials, including metals and organic compounds [2]. Depending on the purpose of the ceramic, the prescribed properties are obtained by using the appropriate raw materials and additives as well as the particulars of the technology, which in turn must be simple and cost-effective.

The object of investigation is aluminosilicate ceramic from the mineral deposits in Amur Oblast with the addition of various pore-formation materials. The objective of the present work is to obtain a porous aluminosilicate ceramic using technical and agricultural wastes to make ceramic filters.

The consumable additive method with dispersion and formation of a mixture — 55% kaolin and 45% quartz-feldspar as the raw materials together with pore-forming additives — followed by sintering was used to make the samples [3]. The mixture was formed under pressure 3 MPa by unilateral pressing of the mix. The material was formed into a cylinder (18 mm in diameter and 25 ± 0.5 mm high) to investigate strength and a disk (30 mm in diameter and 5 ± 0.5 mm high) to investigate water permeability.

Before kilning the samples were dried for 48 h at room temperature and then heated in a muffle furnace to 300°C at the rate 1 K/min; preliminary kilning was performed at 2 K/min to 900°C and final kilning at 2 K/min to 1220°C. After sintering the samples were allowed to cool in the furnace to room temperature.

The following wastes were used as pore-forming materials:

1) rubber mechanicals;

2) crop grains obtained by grinding and pre-sieving through a 0.250 μm sieve;

3) woodworking wastes, sieved through a 0.315 μm sieve.

Samples of porous ceramic were obtained under similar conditions from a mixture of 10% kaolin with 90% talc and no pore-forming additives.

The shrinkage was 20% in samples with crop grain wastes, 14% with rubber mechanicals, and 5% in steatite ceramic.

A DRON-UM1 x-ray diffractometer (CuK_α radiation) and the Debye–Scherrer method were used to study the ceramic samples.

[1] Institution of the Russian Academy of Sciences – Institute of Geology and Nature Use of the Far East Branch of the Russian Academy of Sciences, Blagoveshchensk, Russia.

[2] E-mail: sketz@mail.ru.

Identification of the x-ray diffraction patterns showed that in ceramic samples with filler the main crystalline phase is $3Al_2O_3 \cdot 2SiO_2$ (mullite), whose structure is orthorhombic. In samples without filler the main crystalline phase is orthorhombic $MgSiO_3$. Partially overlapping peaks of a second crystalline phase — SiO_2 — are also observed in the x-ray diffraction patterns.

Porous materials are characterized by a number of parameters, which as whole give a complete representation of the properties of a material.

The porosity of the samples was checked by the fuchsin sample method as well as by scanning electron microscopy performed with a JSM 6390LV JEOL scanning electron microscope at the Analytical Center for Mineral-Geochemical Studies at the Institute of Geology and Nature Use (IGiP) of the Far East Branch of the Russian Academy of Sciences. The data characterizing the porosity of the experimental ceramic samples are presented in Table 1.

Knowing the volume and mass of the dry and water-saturated ceramic sample, we calculated the open porosity P_{op}, water absorption W, and mass specific surface area S_{sp}. We calculated the apparent density ρ_{app}, total and closed porosity P_{tot} and P_c, respectively, the specific pore volume V_p, and the elastic modulus E.

It follows from Table 1 that the woodworking wastes and the method used to make the steatite ceramic pellets give the highest porosity. Ceramic with filler consisting of agricultural wastes have the lowest porosity, the more filler being present, the lower the porosity of the sample at the output. The compression strength τ_c and water permeability k_w could not be measured for samples with filler consisting of agricultural wastes with a 1 : 3 ratio because of the extreme brittleness of the finished material.

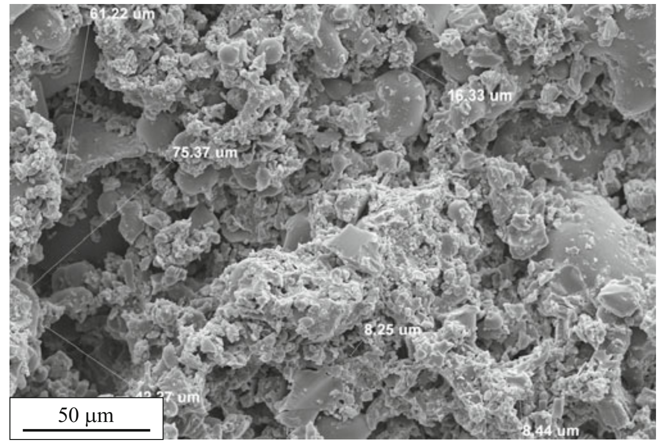

Fig. 1. Photomicrograph of aluminosilicate ceramic with the addition of wastes obtained from grinding crop grains.

It was determined on the basis of the classification of the ceramic structure according to the porosity that three samples possess a highly porous microstructure (> 30%) and three a coarse microstructure (< 30%).

The pore size of the experimental samples was determined by analyzing the electron-microscopic photographs (Figs. 1 – 4), obtained with a JSM 6390LV JEOL scanning electron microscope with an Oxford INCAEnergy (England) integrated energy-dispersion spectrometer-microanalyzer. In the absence of fillers in steatite ceramic the average pore diameter was 15 – 21 μm and the maximum pore diameter $d_{max} = 27$ μm. When fillers are introduced, the average pore size was 35 – 75 μm for ceramic with addition of grain crop wastes, 36 – 71 μm for rubber mechanicals wastes, and 20 – 35 μm for woodworking wastes.

TABLE 1. Indices of the Porous State of Aluminosilicate Ceramic

Index	Ceramic type					
	Electroporcelain				Steatite	
Pore-forming material type	Crop grain wastes		Rubber mechanicals wastes		Sawdust	No pore-forming material
Volume ratio of electroporcelain to pore-forming material	1 : 1	1 : 3	1 : 2	1 : 3	1 : 2	–
Mass specific surface area S_{sp} by mass, cm^2/g	1.475	1.489	1.814	1.695	2.197	1.691
Water absorption W, %	16.80	19.75	9.98	15.27	52.38	42.03
Apparent density ρ_{app}, g/cm^3	1.36	1.34	1.20	1.18	0.91	1.18
Porosity, %:						
open, P_{op}	22.78	26.53	11.96	18.02	47.68	49.72
total, P_{tot}	43.50	44.04	50.08	50.83	62.08	56.98
closed, P_c	20.72	17.51	38.12	32.81	14.40	7.26
Specific pore volume V_p, cm^3/g	0.32	0.33	0.42	0.43	0.68	0.48
Water permeability k_w, liters/min	0.02	–	0.04	0.11	0.09	0.01
Compression strength τ_c, MPa	5.3	–	26	16	5	32
Elastic modulus $E \times 10^3$, MPa	47	20	16	16	10	13

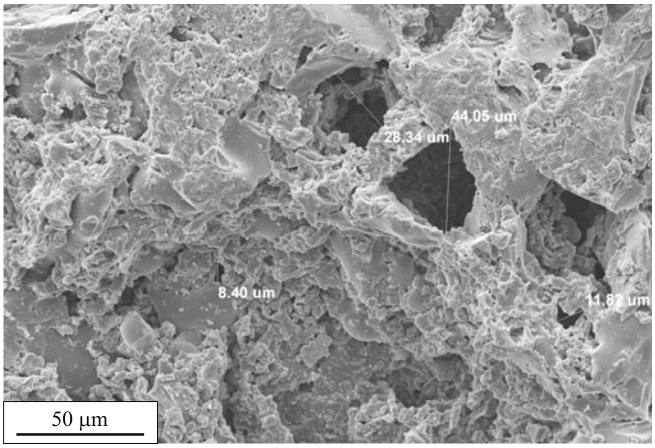

Fig. 2. Photomicrograph of aluminosilicate ceramic with the addition of rubber mechanicals wastes.

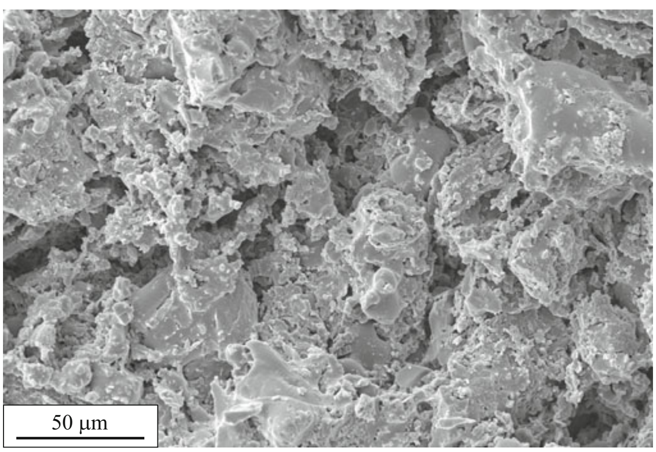

Fig. 3. Photomicrograph of aluminosilicate ceramic with the addition of woodworking wastes.

Complex particle shapes and many particle surface irregularities, attesting to nonuniform material porosity, are observed on all electron-microscopic photographs. The pore shapes are random. There are a large number of constrictions and expansions along the entire length of the pores. Macro-

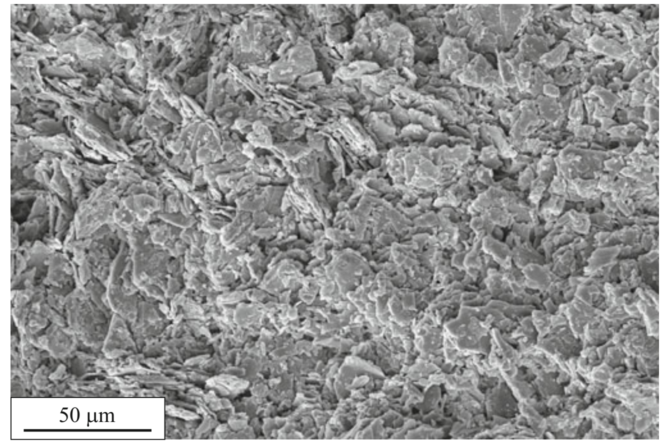

Fig. 4. Photomicrograph of porous steatite ceramic.

irregularities in the form of protuberances and indentations are observed on the surface.

In summary, the method proposed for obtaining steatite porous ceramic and the use of fillers consisting of rubber mechanicals and woodworking wastes make it possible to obtain ceramic for use as filters.

REFERENCES

1. S. N. Kul'kov, V. I. Maslovskii, S. P. Buyakova, and D. S. Nikitin, "Non-hooke behavior of porous zirconium dioxide under active compressive deformation," *Zh. Tekh. Fiz.*, **72**(3), 38 – 42 (2002).
2. S. P. Buyakova, *The Properties, Structure, Phase Composition, and Laws of the Formation of Porous Nanosystems Based on ZrO_2, Author's Abstract of Doctoral's Thesis* [in Russian], Institute of the Physics of the Strength of Materials and Materials Science of the Siberian Branch of the Russian Academy of Sciences, Tomsk (2008).
3. V. A. Demchuk, G. B. Shchekina, N. S. Kostyukov, and A. A. Lukichev, "Fabrication of electroporcelain based on raw materials from Amur Oblast," *Steklo Keram.*, No. 2, 21 – 22 (2009); V. A. Demchuk, G. B. Shchekina, N. S. Kostyukov, and A. A. Lukichev, "Fabrication of electroporcelain on the basis of raw materials from the Amur region," *Glass Ceram.*, **66**(1 – 2), 63 – 65 (2009).